LIQUIDIZATION OF DEWATERED ORGANIC SLUDGE AND ANAEROBIC TREATMENT

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ABSTRACT

Dewatered sewage sludge was thermochemically liquidized at 175 °C and the liquidized sludge was separated by centrifugation to 58% (w/w) supernatant and 42% precipitate. The amount of proteins in the liquidized sludge slightly decreased through the liquidization process, however, that of lipids increased. The supernatant separated from the sludge liquidized with dewatered sewage sludge was successfully anaerobically digested. Biogas yield from the supernatant from dewatered sewage sludge at organic loading concentrations of 1.9-2.2 g VS/*l* during 9 days' incubation was 440 m*l*/g-added VS and digestion ratio was 66% (w/w). Biogas yield in the case of dewatered sewage sludge was 257 m*l* /g-added VS and digestion ratio was 45%. Similar results were obtained in the case of the anaerobically digested with sewage sludge and dewatered sludge. Anaerobic digestion of the supernatants from the liquidized sludges resulted in high biogas productivity and high digestion ratio compared with these of the original sludges. Moreover, the precipitates contained lower moisture, therefore, they can be incinerated easier than the respective original sludges.

INTRODUCTION

Treatments of sewage sludge and anaerobically digested sludge have been important environmental issues to resolve. Anaerobic digestion of sewage sludge is commonly used for treatment of sewage sludge and energy is recovered in the form of methane (Fannin *et al.*, 1983). A thermal pretreatment system for anaerobic digestion of concentrated sewage sludge with 2-3% volatile solid (VS) has been studied to improve anaerobic digestibility and dewatering properties (Haug, 1977; Haug *et al.*, 1978; Haug *et al.*, 1983; Hiraoka *et al.*, 1984). The volume of concentrated sewage sludge for thermal pretreatment is huge, and therefore this process consumes a large amount of energy.

Dewatered sludges (VS of 12%) are clay like solids and are therefore not suitable for anaerobic digestion. An attempt at liquidization of dewatered sewage sludge by a thermochemical process was conducted (Dote *et al.*, 1993; Sawayama *et al.*, 1995). The volume of dewatered sewage sludge decreased markedly from that of concentrated sewage sludge (VS of 2-3%), suggesting that heat treatment of dewatered sewage sludge would require less energy than in the case of concentrated sewage sludge. As for anaerobically digested sludge, thermochemical liquidization can possibly improve anaerobic re-digestibility and the dewatering properties.

This paper deals with the thermochemical liquidization of dewatered sewage sludge and anaerobically digested and dewatered sludge, and the batch anaerobic digestion of the supernatants separated from the liquidized sludges.

METHODS

Liquidization of sludge

Dewatered sewage sludge, and anaerobically digested and dewatered sludge used in the experiment were obtained from an aerobic sewage treatment facility for domestic sewage in Ibaraki prefecture, Japan. The liquidization of the dewatered sludges were conducted as previously demonstrated (Dote *et al.*, 1993). After purging with nitrogen gas, the dewatered sludge was heated at 175°C in an electric furnace and held at 175°C for 1 h in a 1 *l* autoclave (4 MPa). The liquidized sludge was separated by centrifugation (1000 g, 10 min) to supernatant and precipitate.

Anaerobic digestion

Seed sludge for batch anaerobic digestion was obtained from the sewage sludge treatment facility in Ibaraki prefecture, Japan. Two liters of the seed sludge (VS concentration: approximately 1 %, w/w) was incubated in a 2 *l* conical flask at 35°C. A sample was added to the seed sludge at 1.6-2.2 g-VS/*l* and air in the digester was purged with nitrogen gas. Samples for anaerobic digestion included the original sludges (dewatered sewage sludge, and anaerobically digested and dewatered sludge), liquidized sludges and separated supernatants. The gas production yield from the digester was monitored by displacement of saturated sodium chloride solution.

Analyses of sludges and gas

Moisture content was determined by heating the sample at 105°C for 24 h before weighing, and VS and ash content were determined by heating at 600°C for 1 h. Digestion ratio was expressed as the ratio of the amount of VS decrease during 9 or 8 days' digestion to the amount of VS added.

The Kjeldahl-nitrogen method was used for protein analysis. After extraction, a gravimetric method was used for determination of lipids. The Somogyi method was used for carbohydrate analysis.

High heating value (HQ, MJ/kg) for VS of sludges is calculated using to Dulong's formula (Selvig & Gibson, 1945):

$$HQ=0.3383\times C+1.442(H-O/8)$$

where C, H and O are weight percentages of carbon, hydrogen and oxygen, respectively. Low heating value (LQ, MJ/kg) is calculated using the following equation:

$$LQ=HQ\times V-0.0251\times(9\times H+M)$$

where V is the ratio of volatile solid and M is the weight percentage of moisture.

The biogas composition was determined by gas chromatography. The digestion ratio was expressed as the ratio of decreased VS during 9 or 8 days of digestion versus added VS.

RESULTS AND DISCUSSION

Liquidization

Procedures of liquidization and anaerobic treatment for sewage sludge are shown in Fig. 1, and those of liquidization and anaerobic re-treatment for anaerobically digested and dewatered sludge are shown in Fig. 2. Dewatered sewage sludge (moisture, 84%, w/w; VS, 12%, w/w), and anaerobically digested and dewatered sludge (moisture; 84%, w/w, VS; 11%, w/w) were successfully liquidized by thermochemical reaction at 175°C with holding time of 1h. The protein content (33 %) in the sewage sludge was higher than that (28%) in the liquidized sludge. On the other hand, the lipid content (14%) in the liquidized sludge from the sewage sludge was approximately two times higher than that (7%) in the sewage sludge. It was reported that volatile acids would be produced through thermal treatment (170-230 °C) of sewage sludge (Fisher & Swanwick, 1971). These results suggest that proteins were converted to lipids through the liquidization process.

The liquidized sludge from the dewatered sewage sludge was separated by centrifugation to supernatant (58%, w/w) and precipitate (42%, w/w), and that from the anaerobically digested and dewatered sludge was separated to supernatant (46%, w/w) and precipitate (54%, w/w). The moisture content of the precipitates decreased from the both original sludges through centrifugation, therefore, thermal liquidization of organic sludges was considered to be a pretreatment for dewatering.

Anaerobic digestion

The supernatant separated from the sludge liquidized with the dewatered sewage sludge was successfully anaerobically digested. The digestion ratio (66%) of the supernatant was higher than that of the original sewage sludge (45%) after 9 days of incubation. The total biogas yield from the supernatant during 9 days' incubation was 440 ml /g-added VS (Fig. 3) and the total methane yield was 328 ml /g-added VS. The biogas productivity in the anaerobic treatment of the supernatant was improved by thermochemical treatment compared with those of the original sewage sludge and the liquidized sludge. There was no difference in methane contents of biogas (75-77%) among those three anaerobic experiments.

The digestion ratio (61%) of the supernatant from the sludge liquidized with the anaerobically digested and dewatered sludge was higher than that of the original sludge (27%) after 8 days of incubation. The total biogas yield from the supernatant after 8 days of incubation was 339 ml /g-added VS (Fig. 3) and the total methane yield was 253 ml /g-added VS. The biogas conversion ratio of the supernatant based on carbon was 36 %. The improvement in the digestion ratio of the anaerobically digested sludge by thermal pretreatment was more apparent than that of the sewage sludge. This effect was thought to be partly caused by degradation of the cell wall and membrane and to be the same effect caused by the thermal treatment of sewage sludge reported by Haug*et al*, 1978.

Anaerobic treatment of the thermal treatment liquor (average COD; 6-10 g/l) has been studied (Pugh *et al.*, 1987; Kimata *et al.*, 1993). After this preliminary batch experiment, application of the anaerobic digestion method with granular sludge such as the UASB method could contribute to a faster digestion rate for the supernatant from liquidized sludge.

Low heating values of precipitates

The precipitate separated from the sludge liquidized with the dewatered sewage sludge was composed of 71% moisture, 19% VS and 10% ash. The precipitate obtained by centrifugation of the sludge liquidized with the anaerobically digested and dewatered sludge was composed of 76% moisture, 14% VS and 10% ash. This thermochemical liquidization process improved the dewaterability of the dewatered sludges.

The calculated low heating value of the precipitate separated from the sludge liquidized with the dewatered sewage sludge was 1.2 MJ/kg and that of the original sludge was -1.0 MJ/kg. The calculated low heating value of the precipitate separated from the sludge liquidized with the anaerobically digested and dewatered sludge was -0.4 MJ/kg and that of the original sludge was -1.6 MJ/kg. The precipitates separated from the liquidized sludges have higher heating values compared to those of the original dewatered sludges which means that incineration of the precipitate could save energy by using less fuel. A more suitable dewatering method for liquidized sludges would provide higher low heating values for their solid fractions.

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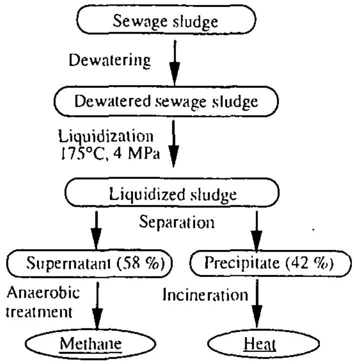

Fig. 1. Flow diagram of liquidization and anaerobic treatment of sewage sludge.

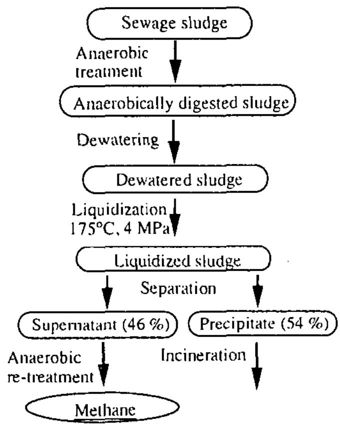

Fig. 2. Flow diagram of liquidization and anaerobic re-treatment of anaerobically digested sludge

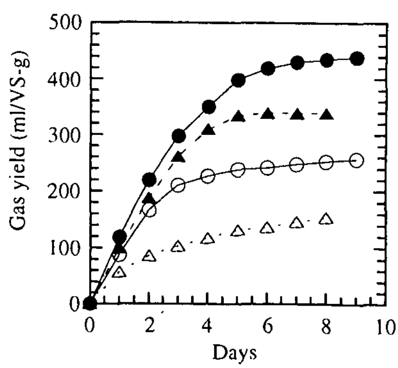

Fig. 3. Gas yield from anaerobic treatments from sewage sludge (open circle) and anaerobically digested sludge (open triangle), and supernatant (closed circle) from sewage sludge and supernatant (closed triangle) from anaerobically digested sludge.